"Investments in Intangibles, ICT-Hardware, Productivity Growth and Organisational Change: an Introduction". Background paper on the NewKind-project: New Indicators for the Knowledge Based Economy

NewKInd

New Indicators for the Knowledge Based Economy

Investments in Intangibles, ICT-hardware, Productivity Growth and Organisational Change: An Introduction

by Huub Meijers and Hugo Hollanders

July 2002

http://www.researchineurope.org/newkind/index.htm

Deliverable 3 D3 Annex 3 to Main Report Deliverable 15 - D15 prepared for 'NewKInd – New Indicators for the Knowledge Based Economy',

Project N: IST-1999-20782

Project Coordinator: SPRU - Science and Technology Policy Research, University of Sussex
Partners: SPRU, University of Sussex. UK
MERIT/International Institute of Infonomics, University of Maastricht, NL
OST, Paris, F

Investments in intangibles, ICT-hardware, Productivity Growth and Organisational Change: an Introduction

Background paper on the NewKind-project:

New Indicators for

the Knowledge Based Economy.

Second draft

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September 2001

Report (Deliverable 3 – D3 Annex 3 to the Main Report Deliverable 15 - D15

Project N: IST-1999-20782

Project Coordinator: SPRU - Science and Technology Policy Research
Partners: SPRU, University of Sussex (coordinator)
MERIT, University of Maastricht
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Abstract

Investments in intangibles, which consist of investments in R&D, education and training, software, royalties and licenses, and marketing, have grown faster than tangible investments in the 1980s and 1990s. Their contribution to US productivity growth has increased significantly in the 1990s, especially in the second half of that decade. The paper argues that investments in ICT are, to some extent, comparable to investments in intangibles and should also be taken into account. The reason for this is twofold: The nature of ICT hardware is more comparable to intangible investments in terms of effects on performance —output and productivity— and it is often argued that ICT infrastructure affects the diffusion of knowledge such that investments in R&D, education and training yield a higher rate of return. So the externalities of knowledge creation become more apparent if this knowledge spreads either faster or more widely or both. The nature of analysis at hand is however closely related to the discussion on the productivity effects of ICT investments. At part of the literature review is also attributed to that discussion.

For a long time, evidence for the productivity improving effects of investments in ICT was hard to find at the macro level. On the micro or firm level, there is ample evidence for these effects. Furthermore, several studies on the firm level have shown that investments in ICT will only result in productivity improvements after a time lag, as it takes time to introduce and implement these investments in a business environment. Simultaneous investments in organisational change are thus required to fully (and timely) reap the benefits of ICT investments. Next to the time lag, investments in intangibles and (in combination with) ICT hardware are assumed to generate spillover effects. The study, of which this paper is a first contribution, with investigate these matters. However, before that can be done, data on intangible and ICT hardware investments, including prices are needed. This paper reviews the existing data and also describes the relation between ICT investments and performance indicators, both at the macro and the micro-economic level.

The next step in research is to calculate stocks of intangibles, including ICT hardware and to analyse the results. This includes a sensitivity analysis of the assumptions made, such as the rate of depreciation, which is not measured directly and which differs considerable among the factors studied, that is, depreciation rates of for instance software are different from those for e.g. R&D investments. The findings will be reported in the next, and final, report of workpackage 2 of the NewKind project.

Introduction

This paper is a first draft as a contribution to the NewKind project: New Indicators for the Knowledge Based Economy. The specific role of knowledge as an input factor in the production process has been (re-) emphasized by many authors and has led to the notions of knowledge based economies. (See e.g. Abramovitz and David (1996), Nonaka and Takeuchi (1995), and Soete and ter Weel (1999)). This also has led to an increased notion of the importance of intangible investments vis-à-vis tangible investments. The measurement of tangibles is, due to a long tradition in economics, business and accounting, fairly standardized and is included in both business statistics as well as in the official statistics. However, the measurement of intangibles is still in its infancy though its importance has been stressed by many authors (e.g. Griliches (1998); Brynjolfsson, Hitt & Yang (2000); Schreyer (2000), Brynjolfsson & Hitt (2000), OECD (2001)).
Also within the programmes of the European Commission there is a focus towards the measurement of intangible investments. For instance, in the MERITUM-project (Measuring intangibles to understand and improve innovation management), ten research groups from 6 European countries have studied this issue mainly from an accounting point of view.[1] Both Eurostat and the OECD also initiated (other) programmes in order to define new measures on the knowledge-based economies and to collect available, sometimes non-harmonized, data.

Main goal of the macro-economic analysis of the new indicators for the knowledge-based economy is to develop a methodology to create stocks of intangible capital. Next to that, an actual construction of these stocks for some European countries is desired in order to analyse the results, which is the third goal. In order to create stocks of various forms of intangible capital, figures on investments, price developments and depreciation rates are needed. This paper reviews the availability of these figures, both in nominal and constant prices. Actual, measured, data on depreciation rates are rare and in most cases linear or exponential depreciation schemes are assumed. This will be handled by some experiments with various assumptions regarding the depreciation schemes. The resulting stocks will be analysed in the tradition of the productivity analysis were, as time and data permit, also attention will be paid to possible spillovers or externalities, which are assumed in the more theoretical oriented literature on human capital and growth. The actual construction of the stocks and the experiments are scheduled in the second part of the project and are not included in this paper.

The next section discusses the current situation regarding the measurement of intangibles in general. In that section, special attention is paid to expenditures in software for two reasons. First software becomes more and more important in the total of intangible investments (determined by the current available measures) and second the methodology of collecting data on software is not clear and differs considerably among countries. The construction of time series in constant prices is even more problematic whereas such

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[1] This project is part of the TSER programme and is co-ordinated by the Autonomous University of Madrid. The timeslot is from October 1998 to April 2001.

series are needed in order to construct stocks or to study the development over time. Moreover, quality adjusted prices give a more realistic view on total output and this will make comparison between e.g. Europe and the U.S. more accurate since the quality adjusted prices are already introduced at some point in the official U.S. statistics as produced by the Bureau for Economic Analysis (BEA) and the Bureau for Labor Statistics (BLS).

Although investments in ICT hardware do not belong to intangible investments as such, we argue that the nature of ICT hardware, being a general purpose technology in many cases that leads to network effects and to externalities, makes this type of investment more comparable to intangible investments rather than being included together with (raw) non-ICT investments. Moreover, it is often argued that the spread of knowledge is being facilitated by ICT hardware infrastructures, which is another, but not less important, argument to treat ICT hardware together with intangibles.[2]

Next we will argue that the investments in ICT are, as such, not contributing that much to efficiency improvements except if this goes along with changes in the organisation. This implies that measurement of (stocks of) ICT, that is IT hardware, IT software and communication equipment, does not tell the whole story. If it is possible to combine information on ICT investments with organisational change, this would improve the information content of the data considerably and this can lead to a new indicator that combines tangible and intangible elements. However, such indicator proves hard to develop. In the macro-economic literature on this topic, it is often assumed that a time lag between ICT investments and productivity changes indicates the time to adjust the organisations to the new ways of work. From that perspective, it is to be questioned whether to time lag should be incorporated in the capital stocks itself as to make a distinction between actual capital stock and the “operational” or effective capital stock. This has to be studied in the future. For the moment, this paper reviews the literature on organisational change and productivity growth.

Finally, this paper draws some conclusions and proposes research steps for the next phase of the project.

Intangible investment: the global picture

Contrary to tangible investments, which are well defined, intangible investments are difficult to characterise. Besides the general agreement that intangibles are non-physical, i.e. they cannot be touched or seen, there are different notions of intangible investments. Croes (1998) defines intangibles for statistical purposes as:
“*Expenditures for all new goal-oriented activities within a country or disembodied tools used in a country. These activities and disembodied tools are aimed at a quantitative change or extension of existing knowledge, or at the acquisition or improvement of*

[2] From the endogenous growth theories the only reason why ICT investments in general, and in Internet technologies in particular, can lead to permanent increases of economic growth is the rapid spread of knowledge such that the innovation process is more efficient/productive.

existing goods, or aimed at the acquisition of completely new knowledge. The results are assets concerning the stock of knowledge, power on the market or strength of the internal organization".

There are several possible classifications of intangibles, for instance with a focus on intangibles as capital or with a focus to types of activities. The first would lead to stocks of human capital, organizational capital and intellectual capital whereas the activities would lead to a focus on R&D, investment in software, education and training and marketing. Another, though related, classification is to capture intangibles in three different bundles: technology, organization and marketing. The literature is not clear on the preferred classification and describes intangibles mainly by the activities as mentioned above. Next to the broad definition of intangible investments, a more narrow is also used frequently and incorporates R&D, investment in software and vocational and higher education. This narrow definition leaves out marketing activities and the lower levels of education and training and can be described as investment in knowledge. So investment in *knowledge* is a part of the total investment in intangibles and the OECD measures it as the expenditures on R&D, (public) spending on education, and investment in software.[3] However, the OECD (1999) argues to include expenditures on marketing, expenditures on design of new goods and investment in organizations (spending on organizational change) as these would be desirable components of investment in knowledge. If these items are included, the difference between investment in knowledge and investment in intangibles disappears completely.

Concerning the different components of investment in intangibles, the expenditures on R&D are measured well and there has been a long tradition in collecting these data. Of course, some problems remain such as the resources allocated to R&D by the higher education sector are often measured poorly and often we find trend shifts in time series but the data are readily available. The distinction between process R&D and product R&D and the relative inputs from researchers, other personnel and equipment for the generation of both types of R&D output is a weak point in many R&D statistics. However, compared to the other investments in intangibles, R&D is measured well. The same holds true for data on education and training, although data other than public expenditures on education are not measured in all countries, and, as stated above, the input from higher education in R&D is not always clear. Investment in marketing is often not registered by the National Statistical Offices (NSOs), but branch organisations do have figures on the expenditures on marketing. For instance expenditures on advertisements are collected by these organisations. The distinction between expenditures and investment is not clear, however. Parts of these expenditures could be classified as operational costs whereas other parts, those expenditures that create market value of the firm by reputation (brand name, good will), could be viewed as investments. Also expenditures (investments) for organisational change are not measured. The second Community Innovation Survey (CIS2), for instance, includes some questions related to organisational change but in this survey, only a yes/no question is asked, not the amount spent on organisational change. Finally, data on software is rather scarce in the official statistics and organisations like the World Information Technology and Services Alliance (WITSA)/International Data Corporation (IDC) and the European Information

[3] OECD (1999).

Technology Observatory (EITO) produce some data. Because the total expenditures on software are considerable —for some countries the expenditures on software are about the same as expenditures on computers— the next section briefly discusses these data.

Software, a special case

The Frascati manual defines software as ‘the mandatory set of instructions for digital instrument operation’ and this comprises software from third parties and internally produced software. A distinction between pre-packaged software, external customized software and internally produced software is the most common breakdown. Some countries have published official national estimates on investment in software according to the System of National Accounts (SNA) but the main source for data is the World Information Technology and Services Alliance (WITSA)/International Data Corporation (IDC) and the European Information Technology Observatory (EITO). However, these data are only provided on the national level and there is no sectoral breakdown. Moreover, EITO makes a distinction between Software products, IT Services and support services. Software products are defined as commercially available packaged programmes, which include system software and application software. IT services include consulting, implementation, operations management. This implies that own account software is completely missing in the EITO figures whereas customized software cannot be separated from other IT services.[4] The World Information Technology and Services Alliance (WITSA)/International Data Corporation (IDC) publishes data on internal software services at the national level and these data are available from 1992 onwards. Moreover, for Italy, the US and the Netherlands National Statistical Offices (NSOs) provide estimates of expenditures on own account software. However, the data from WITSA/IDC and the NSO for the Netherlands differ considerably, both in level as development (see Figure 1). The data for Italy and the US differ in terms of levels but the development over time is similar for both sources: WITSA/IDC and the NSOs.

[4] Croes (2000), however, takes ‘consulting’ and ‘implementation’ as estimates for software services. The definitions employed by EITO are included in the appendix of this paper.

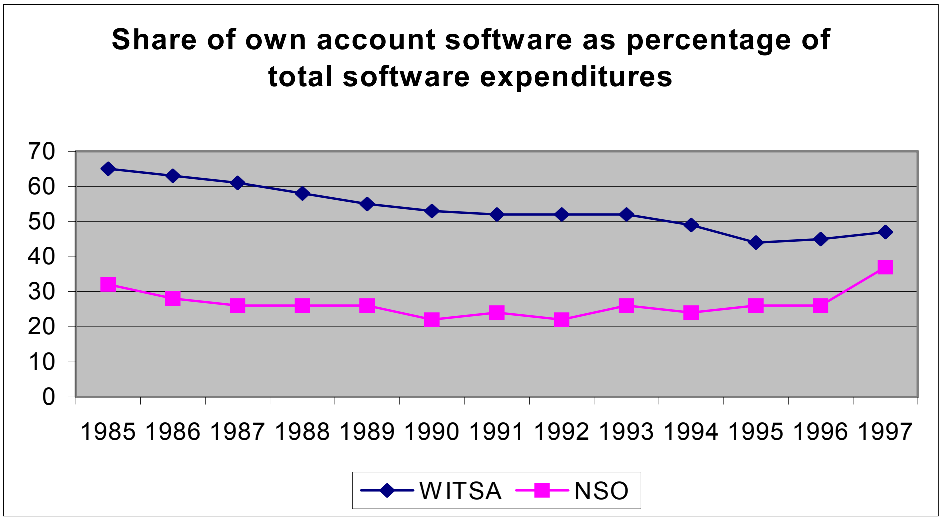

Figure 1. Share of own account software as a percentage of total software expenditures for the Netherlands according to WITSA (IDC) and Statistics Netherlands.

The difference between these two sources is, as far as we can reconstruct, mainly due to the fact that WITSA uses all internal spending for IT as a base to construct expenditures on own account software whereas the figures from the NSOs are based on surveys. Croes (2000) employs three steps to come to an estimate of own account software as compared to total software investments. The data from WITSA/IDC comprise total internal services and cover the period 1992-1999 whereas Croes wants to create data for the period 1985-1999. The first step is to estimate the missing years by retrapolating the data by using the average growth rates of the period 1992-1999. The second step is to calculate the share of own account software in total internal services. This is done by applying the same share for internal services as found for purchased services. So the EITO breakdown between total services and software services is, which is arbitrary to some extent (see footnote 4), applied to total internal services. Finally, the result is compared with the data from the NSOs. Data for Italy and the US showed only differences in levels whereas the data for the Netherlands showed also differences in the development (See Figure 1). Based on the data for Italy and the US, a correction factor is calculated and this is applied to all countries. The resulting data are calculated by Croes and are shown in Table 1. The shares are decreasing for all countries but also show considerable differences between countries. The (unweighted) average decreases by 3 % per year whereas Canada shows the largest decrease of 6.7% per year. Other fast decreasing countries are Australia (5.5%), UK (5.1%), US (5.4%) and Finland (4.7%). Austria (0.8%), Belgium (1.0%), France (1.5%), Germany (2.0%) and Japan (1.1%) show the lowest percentage rates of decrease. Also the levels differ considerable. Italy for instance, for which the constructed data based on WITSA are not that different from the data from the NSO, has clearly the lowest percentage of own account software. Other countries with a relative small share of investments in own account software are UK, US, and Australia. The share in Canada is the highest in 1985 whereas it decreases to about the average in 1997. Countries with high shares of own account software in 1997 are Japan, and Sweden. Although the data give a global picture, the reliability is somewhat doubtful given the way they are constructed, however.

Table 1. Shares of own account investments in software as percentage of total software investments. Source: Croes (2000)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	average annual decrease
Aus	61	61	59	58	57	56	55	57	51	47	46	42	38	5.5%
Aut	47	48	48	47	48	48	47	47	47	45	39	41	43	0.8%
Bel	50	50	49	47	47	47	46	46	48	47	43	43	45	1.0%
Can	71	70	69	67	64	61	57	52	50	49	47	44	41	6.7%
Den	66	64	61	58	57	56	56	57	59	57	50	51	52	2.4%
Fin	65	63	61	48	46	46	48	48	54	53	42	43	43	4.7%
Fra	55	55	56	53	53	51	51	51	53	51	44	45	47	1.5%
Ger	56	57	57	54	52	50	49	48	50	47	43	44	46	2.0%
Ita	38	37	36	34	31	29	28	23	28	28	26	25	26	4.2%
Jap	63	63	60	60	58	55	54	61	60	58	54	55	56	1.1%
Nl	65	63	61	58	55	53	52	52	52	49	44	45	47	3.5%
Nor	52	52	51	48	45	45	45	45	47	45	39	39	39	3.0%
Swe	63	61	59	56	55	55	55	50	57	56	52	50	50	2.4%
UK	50	51	49	48	48	46	44	44	41	39	37	35	32	5.1%
US	51	50	49	48	48	46	44	44	41	39	37	35	32	5.4%
Average	57	56	55	53	51	50	49	49	50	48	43	43	43	3.0%

Another problem with the measurement of software is the distinction between expenditures and investment. In the National Accounts, expenditures on software are only accounted as investment if the corresponding products can be physically isolated. This implies that embedded software is not treated as investment but as intermediate consumption. According to the OECD (2001) there are considerable differences between countries on the treatment of software as investment goods. Only the US make a distinction between pre-packaged software, own account and customized software. Other countries use different classifications or only parts of it. In Table 2 we reproduce the findings of OECD (2001) as to highlight the differences.

	Method of estimate	Source of estimate	
		Purchased software	Own account software
AUSTRALIA		ABS Survey of Information Technology and Telecommunication 1993-94 and 1995-96 as the bench mark for purchased software in the private sector; ABS Survey of State General Government Units 1994-95 as the benchmark for purchased software in the public sector	a survey run by Statistics Canada on "custom software development" and "contract programming" is used for in-house and customised software
CANADA	only software purchases bundled in expenditure for computer hardware	NA	NA
FINLAND	commodity-flow method	software production (in computer and related activities, technical activities, mining & quarrying and manufacturing) + own-account production + imports – exports (from National Board of Customs and Bank of Finland) – consumption (from Household Budget Survey).	
FRANCE	demand-side approach	annual business survey for manufacturing industries and ratio of intangible assets fixed investment to total for other industries	private source
ITALY	commodity-flow method	survey of the System of Account of Business Units" (SAB) and private survey conducted by the National Association of Informatics and Telecommunications Firms (ASSINFORM)	estimates on the basis of the labour cost incurred by firms for software developer personnel.
US	commodity-flow method	estimates are derived from the benchmark 1987 and 1992 Input-Output accounts.	estimates from both intermediate inputs and compensation(wage and non-wage) of employees, with an estimated share of 0.5 of time spent on association tasks

Table 2. Differences in estimating software capital expenditures across six OECD countries
(Source: OECD (2001)

Measuring the impact of ICT on economic performance also requires the creation of stocks of (intangible) capital. However, the creation of stocks on ICT, including software, requires investment figures in constant prices. This is another problem in the statistics on ICT since price developments are hard to measure in this sector, especially if some adjustments are made for changes in quality. Jorgenson (2001) provides some data for the US but it should be noted that these figures are based on some specific case studies and are not representing the whole sector. Schreyer (2000) takes the US data on the development of quality adjusted ICT prices as a basic input in his study on the G7. For instance, he estimates hedonic prices for German Office computing and accounting equipment. The procedure he followed runs as follows: Schreyer starts with hedonic prices of U.S. office computing and accounting equipment. Then he compares this figure with the price developments of non-ICT investment goods. The difference, which is always negative showing a slower growth (faster decrease) of IT prices compared to non-IT prices, fluctuates considerable throughout time. In order to overcome this problem, the data are smoothed by taking a moving average. Finally, the smoothed difference is applied on German (non hedonic) prices as to obtain the final price of office computing and accounting equipment in Germany. The three figures in Figure 2 show these steps.

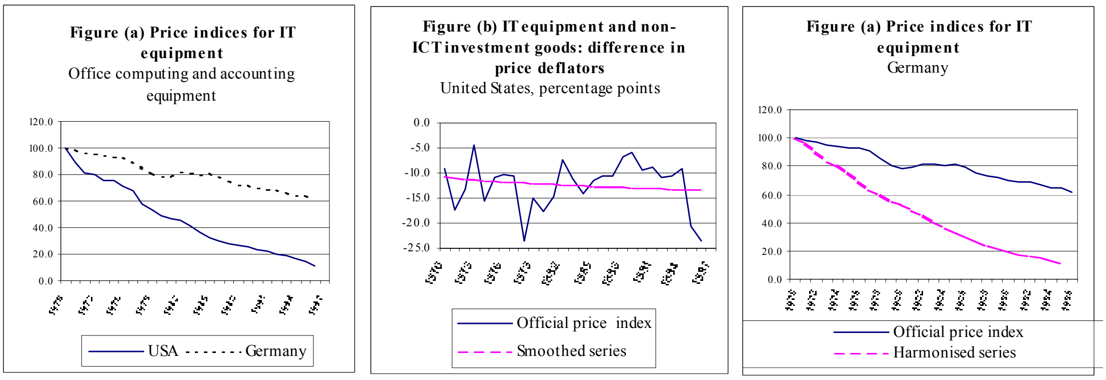

Figure 2. Construction of hedonic prices for Germany on the basis of U.S. data (source: Schreyer (2000), p. 11)

Data on the development of software prices are even more difficult to construct since investment in software encompasses pre-packaged software, own account and custom software. The first category is less problematic since this type of software is purchased over the counter and some data are available. Figures on prices of own account and custom software are hard to measure since they have to include productivity changes of programmers and only indirect methods are available to overcome this problem. Since investment in software is a considerable part of total intangible investments, we conducted a separate study on the issue of price measurement for software, see Hollanders and Meijers (2001).

Investment in intangibles, some data

To give a brief idea on the size of intangible investments, we present some figures on the estimates of intangible investment as compared to investment in tangibles.
If we compare tangible with intangible investment, we see huge differences between various countries, as displayed in Figure 3. In that figure, we show the OECD data on R&D and software as a percentage of total physical investment (marked by OECD) and the data as presented by Croes (2000) on intangible investments as a percentage of investment in machinery and equipment.[5] Because of the nature of knowledge, we also

[5] The OECD data are corrected by: (see OECD (1999), page 16)
-the equipment component of R&D expenditures was subtracted from tangible investment and only included as intangible
-purchases of software by households and operational services were subtracted from investment in software.

compare investment in knowledge (excluding public spending on education) with investment in machinery and equipment (based on OECD data and marked by M&E/intang.) since the latter can be seen as the physical counterpart of knowledge, at least it comes more close than total tangible investments, which also includes buildings and constructions and means of transportation. A lower ratio indicates a higher percentage of investment in knowledge as compared to tangibles and thus indicates a more knowledge-based country. The most knowledge-based countries are the UK, US, Finland and Sweden. The least knowledge-based countries are Australia, Italy, Austria, Norway and Japan. If we look at the investments in machinery and equipment as compared to investments in R&D and software, we see some remarkable differences. For instance, Germany now becomes more "knowledge-based" whereas Denmark drops to the least knowledge-based countries.

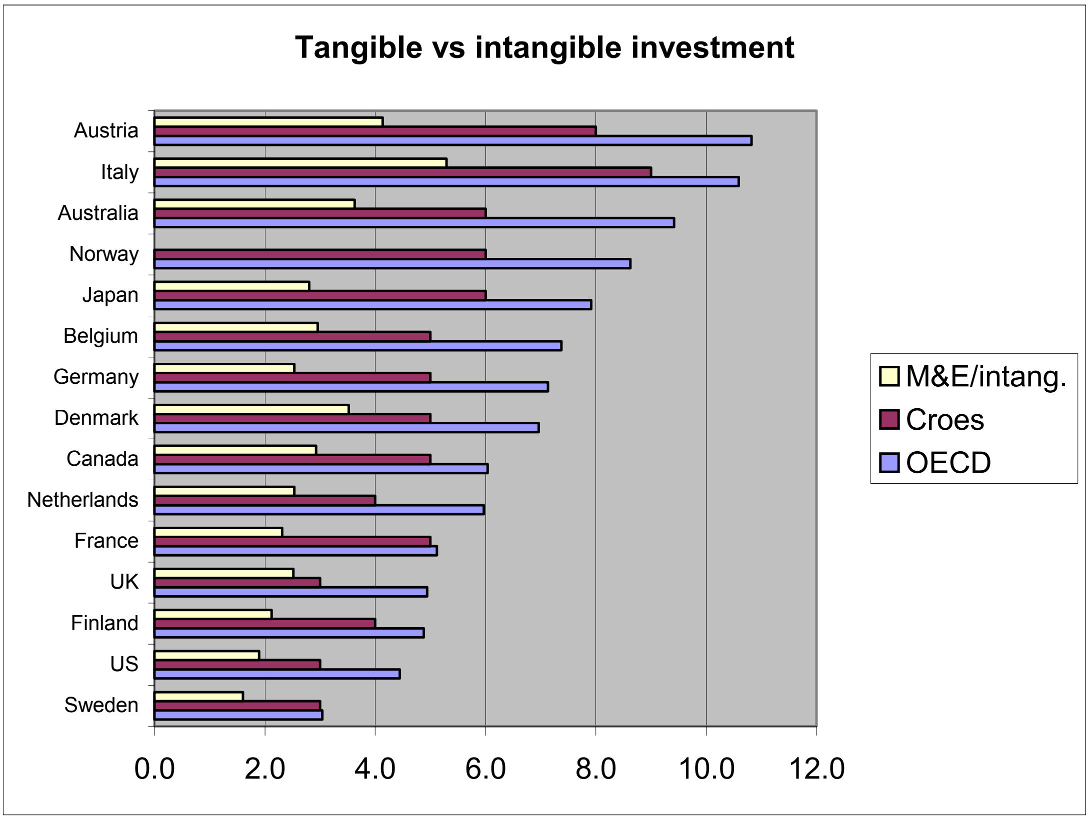

Figure3. Investment in tangible and intangible capital(excl. public expenditures on education). Sources, OECD (1999) and Croes (2000).

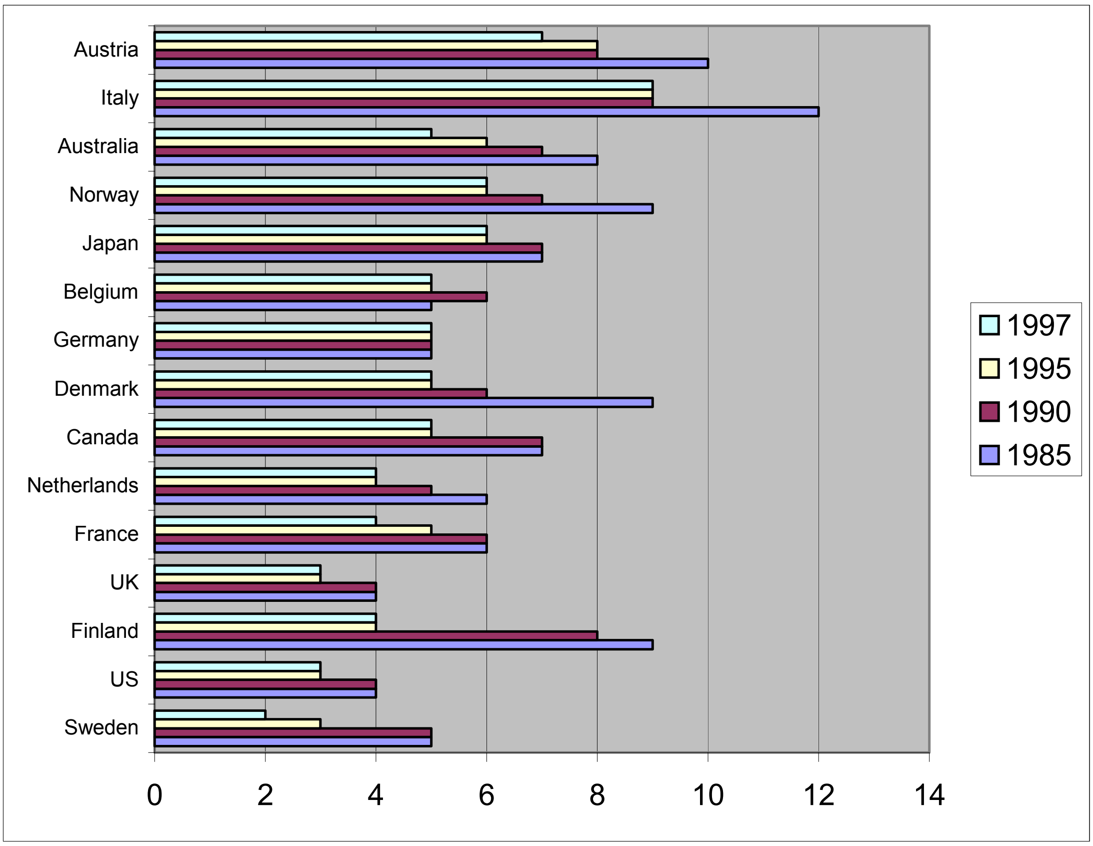

Figure 4. Tangible vs. intangible (excl. Public expenditures on education) investment for several years, based on Croes (2000).

If we compare these data for several years, it becomes clear that all countries, except Germany, have become more knowledge-based as is displayed in Figure 4. Remarkable countries are Finland and Sweden with a rapid decrease of the ratio whereas Germany does not show any change over the whole period while Italy does not show any change in the last decade.

A decomposition of total investments in the Netherlands for several years has been published by the CBS (2000). The data (all in nominal terms) are displayed in Table 3. Here we also include public spending on education in intangible investments. The ratio tangible/intangibles now increases slightly from 2.1 in 1985 to 2.2 in 1997, but leaving out public spending on education also here we see a decrease, i.e. intangible investment becomes more important. Components with the highest growth rates, again measured in nominal terms, are royalties and licences, advertisements and software. Expenditures on education show the lowest growth rate. The ratio of investments in software relative to investments in computers has increased also considerably, showing the increasing importance of software. Note that the prices of items like computers and software declined very rapidly whereas this is less the case for other variables. This means that in constant prices, the contribution from computers and software has become even more important. The software/computer ratio is likely to decline if we would apply quality adjusted prices of these components, because the reduction in prices of computers, at least compared to the quality, is much larger than the reduction of prices of software. This again indicates the importance of quality adjusted prices and Hollanders and Meijers (2001) discuss some results and some problems of the applied methods with a special focus on software.

	1985	1990	1995	1996	1997
bln guilders					
Total	131.3	165.7	190.0	202.0	215.6
Tangible	89.0	114.6	129.2	138.9	148.7
of which:					
Computers	4.0	5.1	6.0	7.0	7.7
Intangible	42.3	51.1	60.8	63.1	66.9
of which:					
Education	25.6	28.0	32.0	32.6	33.2
R&D	8.7	11.1	13.2	14.0	15.0
o.w. business R&D	4.9	5.9	6.9	7.4	8.2
Royalties & licenses	2.4	3.2	4.8	5.0	5.2
Software	2.7	4.6	5.3	5.6	6.9
o.w. purchased software	1.9[a]	3.6	3.9	4.1	4.4
o.w. own account software	0.8[a]	1.0	1.4	1.5	2.5
Advertisements	2.9	4.3	5.5	5.9	6.6
% of GDP					
Software	**0.63**	**0.89**	**0.80**	**0.81**	**0.94**
o.w. purchased software	0.45	0.70	0.59	0.59	0.60
o.w. own account software	0.19	0.19	0.21	0.22	0.34

Table 3. Decomposition of tangible and intangible investments in the Netherlands and the investments of software as percentage of GDP.

Source: CBS (2000).

[a] Data from 1986.

ICT and productivity: Macro economic results

One of the themes discussed in the paper is the relation between investments in intangibles and ICT-hardware and performance. In the introduction it is argued that the relation between ICT investments and performance indicators like productivity growth can be studied from a macro perspective and micro perspective. From the productivity the results are rather different. The macro economic studies rarely find evidence of productivity gains from ICT investments whereas studies at the firm level do. This chapter briefly discusses the macro studies. In the debate on the productivity paradox it has been recognized by many authors that over the 1970's and 1980s, and viewed at the macro-level, investment in ICT does not lead to considerable improvements in efficiency. More recent figures show an increase of the contribution of I(C)T to (productivity) growth as being reported by e.g. Jorgenson (2001) and Oliner & Sichel (2000) for the US, Schreyer (2000) for the G-7, and Daveri (2000) for some European countries.[6]

To start with the US experience, Jorgenson (2001) shows the productivity paradox and the revival of productivity growth in the late 1990s. Figure 5 shows the breakdown of average labour productivity growth into capital deepening, contributions of labour quality and the contribution of total factor productivity on labour productivity. Both capital deepening and the contribution of total factor productivity are broken down into IT contributions and non-IT contributions. This breakdown can be described by the following standard growth accounting equation:

$$\Delta \ln(y/h) = \bar{v}_k \Delta \ln k + \bar{v}_l (\Delta \ln L - \Delta \ln h) + \Delta \ln A$$

where *y/h* is defined as the average labour productivity per hour worked (total output (*y*) divided by total hours worked (h)), k is the ratio of capital services divided by the hours worked, L is total labour input whereas A denotes total factor productivity. The *v*'s denote the average input shares of these factors. The first term, capital deepening, and the last one, total factor productivity, can be broken down into several components: IT related and non-IT related contributions.

[6] It should be noted that the latter two contributions focus more on GDP growth rather than on productivity growth.

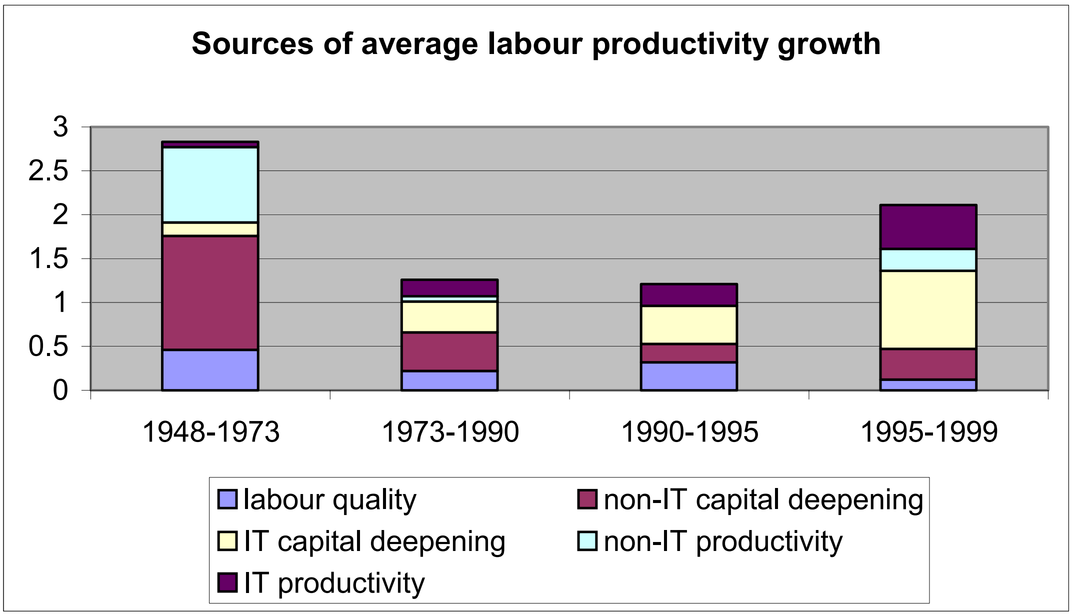

Figure 5. Sources of average labour productivity growth in the U.S.
(Source: Jorgenson (2001), p. 26)

Looking at the development of total average labour productivity, see Figure 5, we see indeed a decline in the period 1973-1995, the period of the productivity paradox, and a revival during the last period from 1995 to 1999. The contribution of labour quality is defined as the difference between the labour input and the hours worked and it reflects the substitution of workers with high marginal product for those with low marginal products. Its influence on average labour productivity growth fluctuates between 0.5 and 0.1. Remarkable is the decline of the influence of non-IT capital deepening from 1.3 percentage points in the period 1948-73 to 0.21 in 1990-95 and 0.35 in 1995-99. The contributions of IT, both as capital deepening and as its contribution to total factor productivity, increased over the years. Note that the sharp decline of IT prices is mainly responsible for this increase. In the study of Jorgenson, the prices are adjusted for changes in quality by a mixture of methodologies: mainly hedonic prices and matched models. Without these adjustments, the contribution of IT to average labour productivity growth would not be that spectacular.

Barro (1998) argues that ICT-investment should be treated different from non-ICT capital since the former is assumed to lead to network effects. That is, the gains from investment in ICT are assumed to increase if more firms invest in these technologies. Schreyer (2000) take up this point and argues that the standard accounting framework is not suitable to incorporate the influence of ICT on (productivity) growth. The 'normal' growth accounting equation is:

$$\Delta \ln y = \bar{v}_{kn} \Delta \ln k_n + \bar{v}_{kc} \Delta \ln k_c + \bar{v}_l \Delta \ln l + \Delta \ln A$$

where k_n denotes non-ICT capital and k_c denotes ICT capital. Rearranging this equation by bringing l to the left-hand-side and by assuming that the input shares of labour, non-ICT capital and ICT-capital add up to one, that is, assuming constant returns to scale, and switching to growth terms, we end up with:

$$\hat{y} - \hat{l} = \bar{v}_{kn}(\hat{k}_n - \hat{l}) + \bar{v}_{kc}(\hat{k}_c - \hat{l}) + \hat{A}$$

where hats denote the growth rate of the variable.

Schreyer (2000) argues that ICT-capital could lead to spillovers due to network externalities and suggests an alternative measure for the output growth:

$$\hat{y} = \bar{v}\hat{l} + \bar{v}_{kn}\hat{k}_n + \bar{v}_{kc}(1+\theta)\hat{k}_c + \hat{A}$$

where θ captures the spillovers due to ICT-capital. Because it is difficult to observe θ directly, and because estimation of the term $v_{kc}(1+\theta)$ usually results into biased estimates, the multi-factor productivity (MFP) approach is used to capture:

$$M\hat{F}P = \hat{y} - \bar{v}\hat{l} - \bar{v}_{kn}\hat{k}_n - \bar{v}_{kc}\hat{k}_c = \bar{v}_{kc}\theta\hat{k} + \hat{A}$$

An upswing in MFP could indicate an increasing importance of ICT. It should be noted that we want to capture the influence of the use of ICT rather than the production of it.[7] Schreyer presents the results of multi-factor productivity growth analysis for the G7. His results are presented in Figure 6.

From these figures we see no clear increase in MFP growth in the late 1990s suggesting that there are no spillovers from investment in ICT. However, the MFP measure is based on a residual, which means that many other factors can have their influence on these results. Moreover, ICT capital is treated as an aggregate whereas one could argue that IT hardware, IT software and Communication equipment and services differ from nature such that their contribution to productivity gains and network effects cannot be seen as just one type of input. Moreover, and as we will argue more precise below, adaptation of ICT requires organisational change and will take therefore time.

More recently, by using other methodologies and longer time series, some authors indeed find a positive relation between ICT investments and productivity growth, leaving out the network effects. However, Gordon (2000) for instance argues that the upswing in productivity growth is mainly due to the increases of productivity in the IT producing sector, next to better, quality-adjusted data. The findings of a positive contribution of IT investments on productivity are often limited to US data. Schreyer calculates the multi-factor productivity growth for the G7 and he cannot find an upward trend in these figures. So the puzzle at the macro-level is still not solved, especially for non-US countries.

[7] See e.g. Gordon (2000) for a discussion on the contribution of the ICT sector to economic growth in the U.S.

Figure 6. Multi-factor productivity growth, total industries, percentage changes over the preceding year. (Source, Schreyer (2000), page 20)

ICT, productivity, and organisational change: firm level analysis

Moving from the macro-economic analysis to the firm level, several authors have investigated the influence of I(C)T investment on performance at the firm level. The first contributions in this field concentrate on the question whether computer investments yield higher rates of return as compared to non-IT capital investments. The first results even indicate that the hypothesis that computers add nothing at all to total output cannot be rejected. (e.g. Barua et al., 1991, and Loveman, 1994) or that the marginal benefits of computer investments are less than the marginal costs (Morison and Berndt, 1990). Brynjolfsson (1993) reviews several studies in this field and he mentions four possible reasons for these disappointing results: 1) mismeasurement of inputs and output, 2) time lag due to learning and adjustment, 3) redistribution and dissipation of IT generated profits and 4) mismanagement of information and technology. Later studies replicated these studies by using other data (most of them use longer time series) and other methodologies and they found different results. For instance Brynjolfsson and Hitt (1994) reject the hypothesis that the marginal product of computer capital does not differ from the marginal product of other capital. Below, we will discuss these results in more detail.

Another, but related theme concentrates on the question whether demand for skills, investment in IT and organisational change are complements or not. This follows the discussion in the tradition of skill biased technological change and, more recently, 'computer' biased technological change. Much of the work relates changes in the composition of the workforce to IT investments and changes in relative wage rates. Here we will concentrate on the influence of ICT investment, organisational change and performance. Most of the work in this field is based on Milgrom and Roberts (1990) who argue that computers should be adopted as a part of a 'cluster' or 'system' of organisational changes in order to be successful. Modern manufacturing, involving high intensity of computer usage may require a radical change in organisations. So investment in ICT alone is not sufficient. This is even more true for investments in Internet technologies since these require a new way of running a business in order to be successful. More recently, several studies also include indicators on organisational change in their analysis (e.g. Licht and Moch (1999) and Bertschek and Kaiser (2001)). These will be briefly discussed below.

We start this brief review with the analysis of Brynjolfsson and Hitt (1994). They posted two hypotheses: *The output contributions of computer capital and IS staff labour are positive* and *The net output contributions of computer capital and IS staff labour are positive after accounting for depreciation and labour expense, respectively.*
They employ a Cobb-Douglas production function using computer capital, non-computer capital, IS staff labour, and other labour and expenses as inputs and the quantity of output as output. The stock of computer capital and IS staff labour is obtained from the International Data Group (IDG) who collect data by surveys among managers of US firms. The data collected comprise the market value of central processors (all types of computers), the total central IS budget, the percentage of this budget devoted to labour expenses etc. It should be emphasized that the survey collects the market value of

computer capital directly rather then obtaining this stock from investment figures. A deflator for Computer Systems deflates this stock. Their results lead to the conclusion that both hypotheses cannot be rejected. Moreover they extended the second hypothesis by asking themselves whether the marginal product of computer capital exceeds the marginal product of other capital. Also this hypothesis cannot be rejected. The gross return on computer capital exceeds the gross return on other capital by 81%, whereas for the net returns computer capital exceeds other capital by 67% and 48%, based on service lives of computer capital of 7 and 3 year respectively.
Dewan and Min (1997) used the same dataset but they estimated a CES-translog production function instead of the Cobb-Douglas. They show that the CES-translog is to be preferred above the Cobb-Douglas. Using the CES-translog, they basically confirm the results of Brynjolfsson and Hitt (1994). They find evidence of excess return on IT-capital relative to labour and also find evidence that IT capital is a net substitute for non-IT capital and labour in all sectors of industry.

Brynjolfsson and Hitt (2000) start their analysis on the influence of investment in computers on productivity in a general growth accounting framework as shown above. Their analysis is applied to a sample of 600 large firms in the US over the period 1987-1994. They start their analysis with a multifactor productivity growth concept and find that computer growth has a significant impact on output growth in the short term, but this impact is not significantly different from the input of computers in the production process. So in the short term computers do not add more value than they cost. However, by extending the time lag, Brynjolfsson and Hitt find that computers in the longer run do yield positive returns larger than their cost share in inputs. Their conclusion is that it takes some time before investment in IT is adopted in the organisations and such that 'as a general purpose technology, the pattern of growth contribution appears to suggest that computers are part of a larger system of technological and organisational changes that increases productivity over time' (Brynjolfsson and Hitt (2000), p. 25).

Brynjolfsson and Yang (1999) start from another point of view and they investigated whether intangible assets, complementary to computers, lead to a higher market value of the firm. They found that, based on a sample of 820 non-financial US firms, an increase of one dollar in the quantity of computer capital is associated by an increase of about 10 dollars in the financial market's value of that firm. They do not find such high valuations for other types of capital. The conclusion is that investment in software, training and organisational change that go along with investments in computers and which do not appear on the firm's balance sheets, create considerable intangible assets. However, it should be noted that if intangible assets are not accounted for, investors may have limited, or even wrong, information about the actual value of the firms. The market values of firms could therefore be overstated.[8]

Bresnahan, Brynjolfsson and Hitt (BBH) (2000) analysed the combination of three related innovations, namely information technology, complementary workplace

[8] One of the goals of the above-mentioned MERITUM project, funded by the European Commission, is to improve the valuation of intangible assets and to promote to include them in the firm's accounts.

reorganisations and new products and services in order to explain skill-biased technical change in the US. They found, on the basis of firm-level data, evidence of the complementarity among the three types of innovation. Moreover, they also found evidence on the importance of this mix on factor demand and, for our use more importantly, productivity. So “skilled labour is complementary with a cluster of three distinct changes at the firm level: information technology, organisational change and new products and services.” (BBH, 2000, p. 20).

Licht and Moch (1999) use, contrary to all other studies mentioned here, German data to investigate the productivity effect of IT investments with a special attention to the service sector. They base their results on the Manheim Innovation Panel for the Service sector, a mail survey on the innovation behaviour in the service sector carried out in 1995-1996. Because it is assumed that different types of computer capital have different impacts on output and productivity, they distinguish terminals, UNIX workstations and PC’s. They employed a linear homogeneous Cobb-Douglas production function and related labour productivity with computer capital, materials and the different types of computer capital, and also added firm size dummies and industry dummies. The results show that only PC’s have an impact on labour productivity that is significantly different from the influence of capital. This view also supports the idea of PC’s as being a General Purpose Technology whereas this is not true for mainframes and workstations. Effects of organisational change are not analysed by Licht and Moch, however. Bertschek and Kaiser (2001) take this point and they analysed, on a sub-sample of the same survey, the influence of organizational change on labour productivity. They use three forms of organizational change: enhancing group work, flattening hierarchies and the creation of profit centres. The first two prove to have significant influence on productivity whereas this is not the case for the creation of profit centres. Moreover, the influence of IT investment is positive in all cases. This research confirms the analysis of Bresnahan et al. (2000) that workplace organisation is an important factor in the determination of productivity growth, along with other factors such as investment in IT.

Conclusions: next steps in the research

The influence of intangible capital has become more important in the western economies in the last decades, though the measurement of intangibles is still in its infancy, at least at some parts. Components of intangibles, classified to different types of activities, are: R&D, software, education and training, marketing and organisational change. We argued that software is measured not that well, especial the custom and own account software. Moreover, and at least as important, measurement of price developments are rare, and are, at best, based on partial studies, both in time and in terms of coverage. We therefore decided to pay attention to the measurement of software prices in a separate contribution (see Hollanders and Meijers (2001)).

Next to, and often in combination with investment in intangibles, the influence of investments in Information and Communication Technologies (ICTs) on performance (output growth and various measures of productivity growth) has been studied both at the macro and the firm level in many studies. At the macro-level the results are mixed. Some show a significant contribution of ICT investment to output growth and productivity growth whereas others find no evidence of the influence of ICT. Within the field of Management of Information Systems it has been argued already for a long time that investment in ICT is not the sole solution to obtain efficiency gains or productivity growth. Two different, though interrelated, arguments are: it takes time before investment in ICT can have a positive effect and organisations should be reorganized in order to make investments in ICT profitable.

Using data at the firm level, also mixed evidence is found on the influence of ICT on productivity. Some authors find no positive influence of I(C)T capital on productivity, Others find a positive influence, but not significantly different from non-IT capital whereas a third group finds evidence that IT capital has a significantly different, and positive, influence on productivity compared to non-IT capital. Next to pure investments in IT, some authors take also organisational change into account and they find that organisational change, especially in combination with investment in I(C)T, leads to large productivity gains and increases output considerably. We expect that this is even more the case for investments in Internet technologies in order to improve efficiency (supply-chain management, e-commerce etc.) since also this technology can be seen as a General Purpose Technology.

However, data on organisational change and the combination of organisational change with I(C)T investments are not available at the macro- or sector-level. One way to cope with this problem is to distinguish between ICT investments that go along with organisational change and those investments that are not. The assumption is that the first would be more productive than the latter one. However, such an analysis is not easy since firms may have changed their organisational structures in the past such that current investments are embedded in an organisation that is already well prepared and adjusted. So this would require some notions of a stock of organisational change or "organisational adaptive capacity". This implies that the results from e.g. the Community Innovation Surveys cannot be used directly to construct a notion of the "stock of organisational change" or the organisational adaptive capacity. This is possible if sufficient long time series on these data become available. Another approach is to depart from the more macro-economic perspective that says that organisational change will show up as a time lag between actual investment and the ultimate effects on output and productivity. Although this methodology would suffer from the same problems as the micro approach as suggested above —some investments are imbedded in prepared organisational structures and others not— the analysis can be carried out more easily and "only" requires longer time series. Moreover, some microeconomic studies on the time lags show promising results.

We therefore will take up the research along this macro-economic line and will first measure the influence of intangible investments and ICT-hardware investments, being transformed into stocks, on output growth and productivity growth. We will analyse possible externalities and time lags as to point out the nature of these types of investments. Such analysis can lead to a measure for the actual and the effective amount of intangible capital taking account of the special nature of intangibles and ICT.

As noted above, the study also includes —and has to include— data on prices since these data are needed in order to construct stocks of intangible and ICT-hardware capital. Moreover, assumptions regarding the development of prices and the rate of depreciation are also needed and since both are not measured directly, the final report will contain some sensitivity analysis regarding these assumptions.

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Appendix I. Definitions of software products and IT services as employed by EITO.[9]

Software products are commercially available packaged programmes for sale or lease from systems services and independent software vendors (ISVs). Value includes the packaged software fees plus related non-consulting revenue, such as fees f or maintenance and/or sup-port. The software products category includes license fees partially earmarked for software maintenance, services, and/or support; other forms of software support would be counted within the support services category. This definition does not include consulting or system integration revenue or specially designed application software solutions added by turnkey systems houses (including VARs) to systems acquired from a hardware manufacturer or other third party. The primary categories are: systems software and utilities, application tools, and application solutions.

Systems software includes system infrastructure software and application tools.

– System infrastructure software is divided into four primary categories. System management software is used to manage the full range of computing resources for the enterprise. Middleware is defined as independent system software and services that distributed businesses use to share computing resources across heterogeneous technologies. Server ware delivers capabilities to coordinate resources between distributed servers or nodes on the network. System-level software is the foundation of system software products that collectively operate the hardware platforms and communications networks upon which business applications are built. System-level software includes operating systems and subsystems, networking software and services, and system utilities.

– Application tools include information access tools and programmer development tools. Programmer development tools are products that support the professional developer in the design, development and implementation of a variety of software systems and solutions. Examples include database engines, 4GL, AMD (analysis, modelling and design) and 3GL.

Application software includes consumer, commercial and technical programmes designed to provide packaged software solutions for specific problems inherent in the home, industry or in a business function. Such software can address consumer applications, “cross-industry” applications (e. g., accounting, human resource management, payroll, project management or word processing and other office activities) or specific industry applications for vertical markets (e. g., banking/financial, manufacturing, health care, oil and gas exploration, etc.).

IT services

Consulting: encompasses a broad array of IT- related planning and design activities that assist clients in making IT-related decisions on business direction or information technology. IT-related business consulting includes corporate strategy assistance, process improvement, capacity planning, best practices, business process re-engineering, and change management services for business; not included are consulting involving tax, audit, benefits, financial, and/or engineering issues. IT consulting includes: information systems strategy assistance, information system and network planning architectural and supplier assessments, product consulting and technical designs for information techno logy, and maintenance planning.

Implementation: comprises all activities directly involved with the creation of technical and business IT solutions, specifically with procuring, configuring, installing, developing, moving,

[9] Copied from EITO (2001).

testing and managing information technology. Implementation services also include all activities involved with custom application development and work performed on packaged applications. Training and education is also included in this segment. It includes activities required for the transmission of new behaviours, skills or actions that can be used to begin performing job-specific tasks or improved performance in IT-related functions.

Operations management: involves taking responsibility for managing components of client's IT infrastructure. Specific activities include help-desk services, asset management services, systems management, network management, software update management, facilities management, back up and archiving and business recovery services. Processing services are also included under this category.

Support Services: include all activities involved with ensuring that hardware, software and networking products are performing properly as a service to clients. Activities include all maintenance contracts f or hardware, software and networking products, as well as services, such as telephone support to resolve problems for clients and help with workarounds. Services in this category can come as bundled package of other services or stand-alone.